Enhancement of Energy Efficiency using a transition state MAC Protocol for MANET

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Abstract: A mobile ad hoc network (MANET) is generally outlined as a network that has several free or autonomous nodes, usually composed of mobile devices or different mobile items that can arrange themselves in numerous ways and operate without strict top-down network administration. Energy efficient lifetime maximizing methods based on channel awareness in MANETs result in better performance of the networks until the node's energy is capable of handling control messages. In the existing approach, the node's lifetime and consistency of packet flow is defaced due to unplanned energy conservation methods. This results in a tradeoff between network throughput and node energy, resulting in post network failure. The post network failure results in limited TTL of the nodes and retarded network throughput with higher control overhead. To bridge the gap between network throughput and energy conservation under limited overhead, a Transition State supporting cooperative MAC broadcast protocol for both conserving node energy and to utilize available node in an effective manner prior to their energy drain is proposed in this paper.

Key Words: MANET, MAC, Node density, transition state, Energy consumption

1. Introduction

Wireless mobile ad hoc networks (MANETS) are self-configuring, dynamic networks in which nodes are free to move and it does not rely on a pre-existing infrastructure, such as routers in wired networks or access points in managed wireless networks.

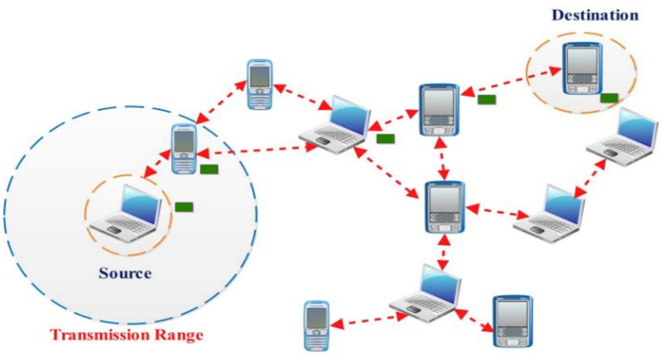

Figure 1: Simple Mobile Ad-hoc network

In day to day life, the increasing mobility of humans across the globe generated demand for infrastructure less and quickly deployable mobile networks. Such networks are referred to as Mobile Adhoc Networks (MANET). Fig 1 shows a simple mobile ad-hoc network or MANET. Maximizing the nodes lifetime and thus the network lifetime is a common objective of Adhoc networks. Since the Adhoc nodes are assumed to be dead when they are out of battery, it is imperative to optimize the battery consumption at the nodes.

The number of mobile nodes in MANET works not only as hosts but also as routers, and communicate with each other via packet radios. Since nodes in MANET are not connected to a power supply and battery replacement might be problematic, enhancing the energy consumption in these networks has a high priority and power management is one of the most difficult issues in ad hoc networking. And also these networks suffer from high power consumption, inefficient spatial reuse, and poor Quality of Service. These issues can be overcome by developing a medium access control (MAC) scheme that reduces power consumption by sending at the minimum power expected to attain the nodes concerned in a connection, and whichenhances spatial reuse by permitting as many simultaneous exchanges as possible to occur in an area.

In the existing approach (i.e.) Static Power Consumption MAC protocol (SPCMP) and Dynamic Power Consumption MAC protocol (DPCMP), the node's lifetime and consistency of packet flow is defaced due to unplanned energy conservation methods. This results in a trade-off between network throughput and node energy, resulting in post network failure. The post network failure results in limited TTL of the nodes and retarded network throughput with higher control overhead. To bridge the gap between network throughput and energy conservation under limited overhead, a Transition State supporting cooperative MAC broadcast protocol for both conserving node energy and to utilize available node in an effective manner prior to their energy drain is proposed in this paper.

1.1 Medium Access Control Protocols for Ad-Hoc Wireless Networks

Nodes within the wireless network share a standard broadcast radio channel. Since the radio spectrum is limited, the bandwidth available for communication in such networks is additionally restricted. Access to this shared medium need to be controlled in such a manner that each node receives a fair share of the available bandwidth, and the bandwidth is used efficiently.

1.2 Classifications of MAC protocols

MAC protocol for ad-hoc network may be classified into different types based on various criteria. Adhoc - MAC protocol is classified into 3 basic types:

a) Contention based protocols.

b) Contention based protocol with reservation mechanism.

c) Contention based protocol with scheduling mechanism.

1.2.1 Contention Based Protocol

These protocols follow a competition based mostly channel access policy. A node doesn't build any resource reservation prior. Whenever it receives a packet to be transmitted, it contends with different nodes for access to the shared channel. They are further divided into two types:

Sender initiated protocols - packet transmissions are initiated by sender node.

Receiver initiated protocols - the receiver node initiates the competition resolution protocol.

1.2.2 Contention Based Protocol with Reservation Scheme

Ad-Hoc wireless networks typically may have to support real time traffic, which needs QoS guarantees to be provided. So as to support such traffic, certain protocols have the mechanism for reserving bandwidth in prior. Such protocols will guarantee QoS to time sensitive traffic sessions. These are further divided into two types:

Synchronous protocols - these systems need time synchronization among all the nodes within the network.

Asynchronous protocols - they do not need any global synchronization among the nodes.

1.2.3 Contention Based Protocols with Scheduling Mechanisms

These protocols target packet scheduling at nodes and additionally scheduling nodes for access to the channel. Node scheduling is completed in an exceeding manner so all nodes are treated fairly. Scheduling based schemes are alsoused for implementing priorities among flows whose packets are queued at nodes. Some scheduling schemes additionally take into consideration battery characteristics, like remaining battery power, whereas scheduling nodes for access to the channel.

2. Literature Review

This section provides the summary of related work by various authors in routing protocols:
In the earlier days, ad-hoc networks had several problems like high power consumption, inefficient space utilizes, and security analysis that created it as flawed architecture.A lot of analysis has been done on this specific field, it's typically been questioned on whether or not the architecture of Mobile Ad-hoc Networks may be basically a flawed architecture [1].

Then the research has been done to reduce the control overhead by using the domination set based routing. The nodes which use to connect all the other nodes in the network are called dominating nodes, and the set of dominating nodes forms domination set. This new approach provided, finding the route and reducing the reroute establishment delay and increasing the packet delivery ratio [2].

A power control scheme has been proposed for directional MAC protocol which needs the utilization of a single channel for the transmission and for the reception of both control and data packets. Using the temporal transmission power correlations that exist between the directional MAC protocol 4-way handshakepackets (RTS/CTS/DATA/ACK) for successful communication taking into accounts directional operational access problems like hidden terminal problems, deafness and side lobe interference. Based on the node activity density, an interference model was estimated and together with the correlations derived and able to induce efficient constraints that make sure the correct delivery of every individual frame in this 4-way handshake. With this technique throughput gains and prolonged life time can be achieved [3].

Several studies were dealt with the survey of various research in this field provides the essential concepts of innovative research in the field of MANET. This research work provides the knowledge about the work in the field of energy efficient issue. Every research contribution within the field of energy is effective and enhancement and modification also may provide better results as compared to existing one. The proper energy efficient routing provides the less dropping of data packets and by that the retransmission of data packets are minimized and energy is utilized properly [4].

In reality, node energy utilization needs to be balanced so as to extend the energy awareness of networks. The main constraints in mobile ad hoc networks are more possibility of node failure is owing to energy uncertain depletion. So, if some nodes die early then these nodes additionally affected to alternative nodes due to lack of energy also they can't communicate with oneanother. The multipath routing protocol provides the better and reliable communication. The main consumption source of energy is transmission then receiving in the network. The proper energy profitable routing provides the less dropping of data packets and by that the retransmission of data packets isreduced and energy is used properly [5].

After that a channel-based routing metric is proposed that utilizes the average nonfading duration, combined with hop-count, to pick stable links. A channel-adaptive routing protocol with Ad hoc On-Demand Multipath Distance vector CA-AOMDV, extending AOMDV, supported the proposed routing metric, is introduced. Throughout path maintenance, expected signal strength and channel average attenuation period are combined with the handoff to combat channel attenuation and improve channel utilization [6].

Then EE-MAC, an Energy-Efficient MAC protocol for mobile ad hoc networks was introduced. The goal of EE-MAC was to reduce energy consumption in an ad hoc network without significantly reducing network performance. The key idea is to elect some nodes to form a connected dominating set and use this as a virtual backbone to route packets, while other network nodes, called slaves, stay in power-saving mode. EE-MAC is a cross-layer design which spans the network layer and the MAC layer [7].

The problem with original MAC protocol is its static behavior. It suggests that at every collision its waiting time will increase exponentially and at every successful transmission, it's waiting time decreases one slot at a time. Because of the static behavior of existing 802.11 MAC protocol, a new modified algorithm that is Adaptive in nature and changes with time was proposed. In the newly proposed technique, the algorithm change its behavior according to load variations and at each collision waiting time will increase another outlined manner so that the contention window size will increase slowly [8].

3. Proposed Work

In this section, an overview of proposed protocol is introduced. Actually in this research; a Transition State supporting cooperative MAC broadcast protocol(i.e.) Transition State MAC Protocol (TSMP) for both conserving node energy and to utilize available node in an effective manner prior to their energy drain is proposed.The status of the MAC layer can be modeled by a Markov chain. The states of this Markov chain depend upon the MAC layer employed by the sensing element node. For example, if the IEEE 802.11 MAC layer is considered, then there will be three operational modes/states. Transmits, Receive and Idle. Each state corresponds to a different power consumption level.

State 1 (Idle):Even when no messages are being transmitted over the medium, the node stays idle and listening to the medium with idle power.

State 2 (Transmit):Node is transmitting a frame with the transmission power.

State 3 (Receive):Node is receiving a frame with the reception power.

If the sensor node uses IEEE 802.15.4 or SMAC as a MAC protocol, fourth state is also available.

State 4(Sleep): The radio is turned off and therefore the node is not capable to detect signals. It is supposed to be the node uses a power in this state.

In this, some transitions (Idle-Transmit, Idle-Receive, and Sleep-Idle) aren't instantaneous. These specific transitions are achieved with an additional amount of energy in a requested amount of time. To take account of the transition delay, three virtual states representing the state of the radio module during transitions was introduced.

State 5 (Pre-Idle):A virtual state that inevitably precedes the idle state in the transition Sleep-Idle.

State 6 (Pre-Transmit):This virtual functional mode models the state of theradio module during its transition to the state Transmit.

State 7 (Pre-Receive): An intermediate state acquired by the radio module when transiting to the functional mode Receive.

Our aim is to design an algorithm that has a capability to use optimum power for control and data packets. The protocol environmental assumptions are characterized as follows:

- The nodes in the network have same initial energy.
- The node's whose energy is below threshold will be discarded from the relaying process.
- Each of the nodes must update its current energy level to its predecessor post each transmission.

Once the source discovers the neighbours for relaying, the first routing path to the destination is selected based on shortest distance. The nodes that form the shortest path will be in transmission state and the rest of the nodes will be move to idle state. In idle state the receiver radio hardware will alone be kept in ON state and the node functions will be halted so as to prevent the node from receiving unnecessary broadcast. After each transmission, the nodes in transmission state will update their energy level (despite of the destination) to their predecessor nodes. The predecessor nodes verify the broadcasted energy level with the threshold of each node. If the current energy level of the node is higher than the threshold, then relaying continues, else the node needs to be replaced.

3.1 System Model

In this section, the modelling approach to analyse the behavior of the MANET was introduced. The traditional adhoc network maybe considered as an undirected graph which consists of n no of nodes and an idle set of $\{I\}$. Sink node may be placed either inside or outside the area to be monitored.There exists a link between node i and node j if the Euclidean distance d(i,j) is not larger than the radio transmission radius. Here, undirected graph means bi-directional communication link. In other words, if node j can receive the packet from its neighboring node i, it is believed that node i can receive the packet from node j in a reverse way. The objective of this paper is to find optimal distances during routing process so that the energy can be saved and utilized in an effective manner.

3.2 Energy Model

Let E_t and E_r be the transmission & reception energy of a node. Then the energy consumed by the node can be calculated as,

$$E_c = E_t + E_r$$

Where,

E_c – Energy consumed by the node

The threshold energy can be calculated as,

$$E_{th} = \frac{\sum_{i=1}^{k} E_c(k)}{k}$$

Where,

k – Total no of transmission

The predecessor node must satisfy $E_c < E_{th}$

If the above condition fails, then the current active node is replaced with a node in sleep side (i.e.) $i \in \{I\}$

Where $\{I\}$ denotes the Idle state set

In case if $E_c > E_{th}$, then the node upgraded to active state. This process continues till the active nodes in the transmission reaches the destination.

Whereas in the MAC based post relaying process the residual energy of a node is given by,

$$E_{res} = E_i + E_c$$

Where,

E_i – Initial energy of the node

E_c – Energy consumed by the node

If residual energy of the current node is less than the threshold energy (i.e.) $E_{res}(i) < E_{th}(i)$, then the MAC protocol is upgraded to the next node j and the response time is validated.

Now the reply time between the previous node and next node is checked so that the node with minimum delay can be chosen for next transmission.

$$\text{(i.e.)} \quad t_j < t_h$$

Where,

t_j - Response time of next node, j

t_h - Response time of previous node, h

So with this proposed technique, both energy optimization and utilization is achieved.

3.3 Threshold estimation of the node

The threshold of a node is defined based on it average energy consumption. The average energy consumption of a node is defined as the ratio between summation of energy utilized throughout the transmission and the total number of transmission the node has undergone.

The total number of transmission includes both the successful and unsuccessful transmission count.

Ave energy consumption =

$$\frac{\sum \text{Energy utilized throughout the transmission}}{\text{Total no of transmission the node has undergone}}$$

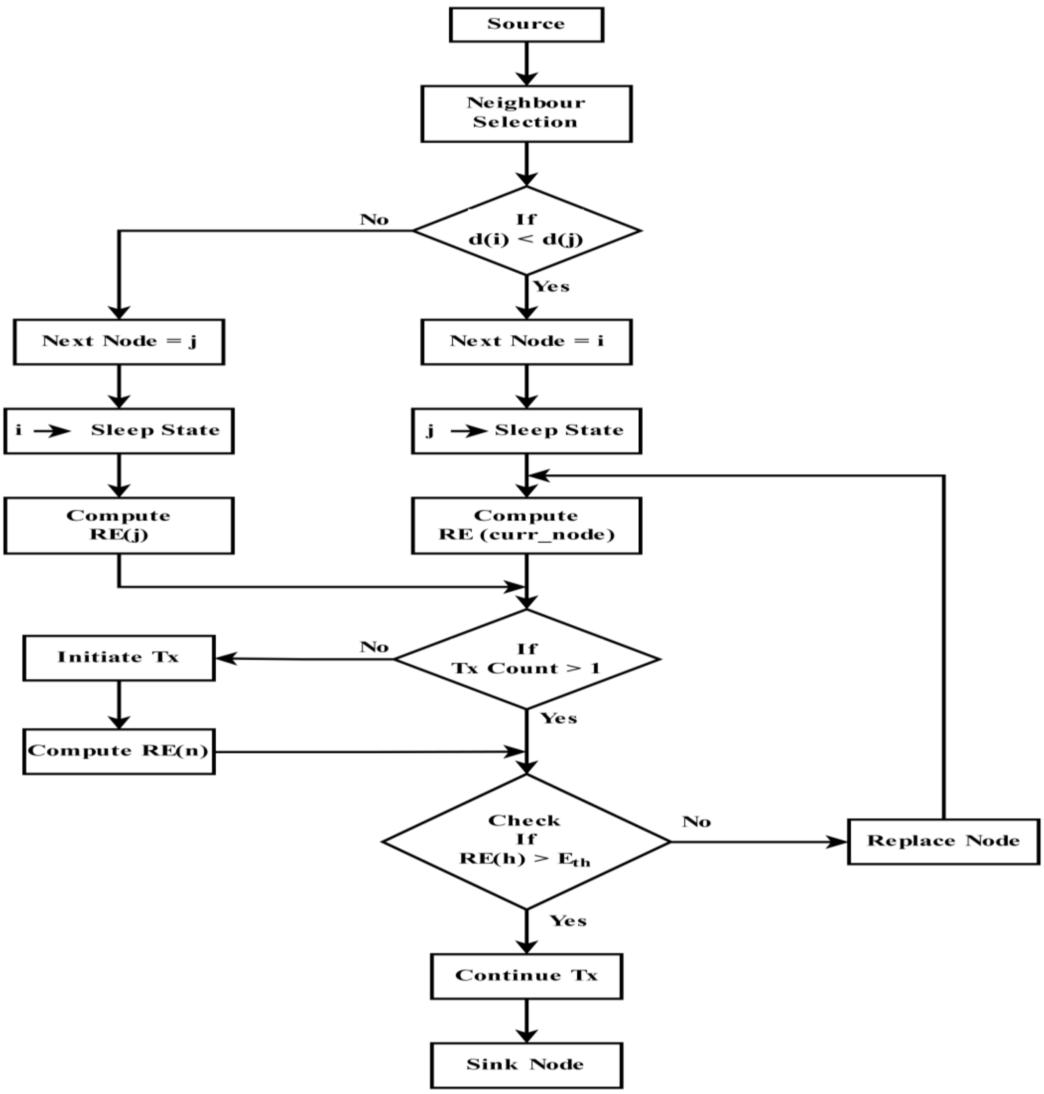

Figure 2: Energy Based Neighbor Selection

3.4 Post Replacement Relaying Process

In the post relaying process, other than changing the entire routing path, the nodes that lag the threshold condition will alone be replaced with the neighbor located. In such case, the replacing node broadcasts a MAC with its energy level to its neighbor; pursuing the current transmission process besides. The in-range neighbor receives the request MAC and moves to transmission state to take over the relaying of the replacing node. Here, the replying MAC must be in synchronized manner with the request MAC with minimum time difference or time difference that is same as in the case of neighbor discovery. Once the new node comes to transmission state the replacing node moves to idle state. If the replacing node moves to idle state, the energy of the node is verified with its transmission eligible (minimum transmission) power. If the node's current energy meets the requirement of the transmission eligible state, the node will be recalled for replacement else, the node will be left alone with minimal energy, ensuring the node is not dead until it is recharged or replaced once for all.

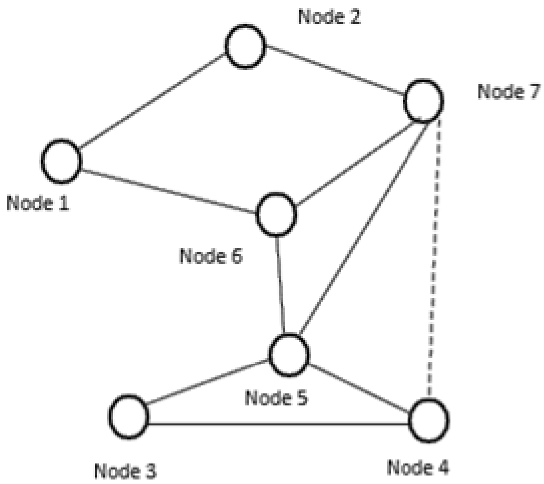

Figure 3: Node selection based on energy level

Fig 3shows the concept of node selection and energy optimization in TSMP. In the existing methods (SPCMP and DPCMP), the nodes (say node 4) which lag the routing path and threshold energy will be replaced by the neighbor node. But in this new approach E_{res} and E_{th} of predecessor node and current node is compared and the node is updated based on their energy levels. So that the available nodes can be utilized and energy can be saved in an efficient manner.

3.5 Control Overhead Minimization

Unlike SPCMP and DPCMP techniques, in the proposed method, the nodes need not broadcast MAC in a periodic fashion so as to update its state. It is enough if the nodes broadcast MAC and receive a reply MAC if the node is nearing its TTL. Besides, the source need not initiate a new broadcast as the neighbor information is already stored in its RT. Therefore, limited neighbors will be broadcasted with the control messages that prevent unnecessary transmission halts.

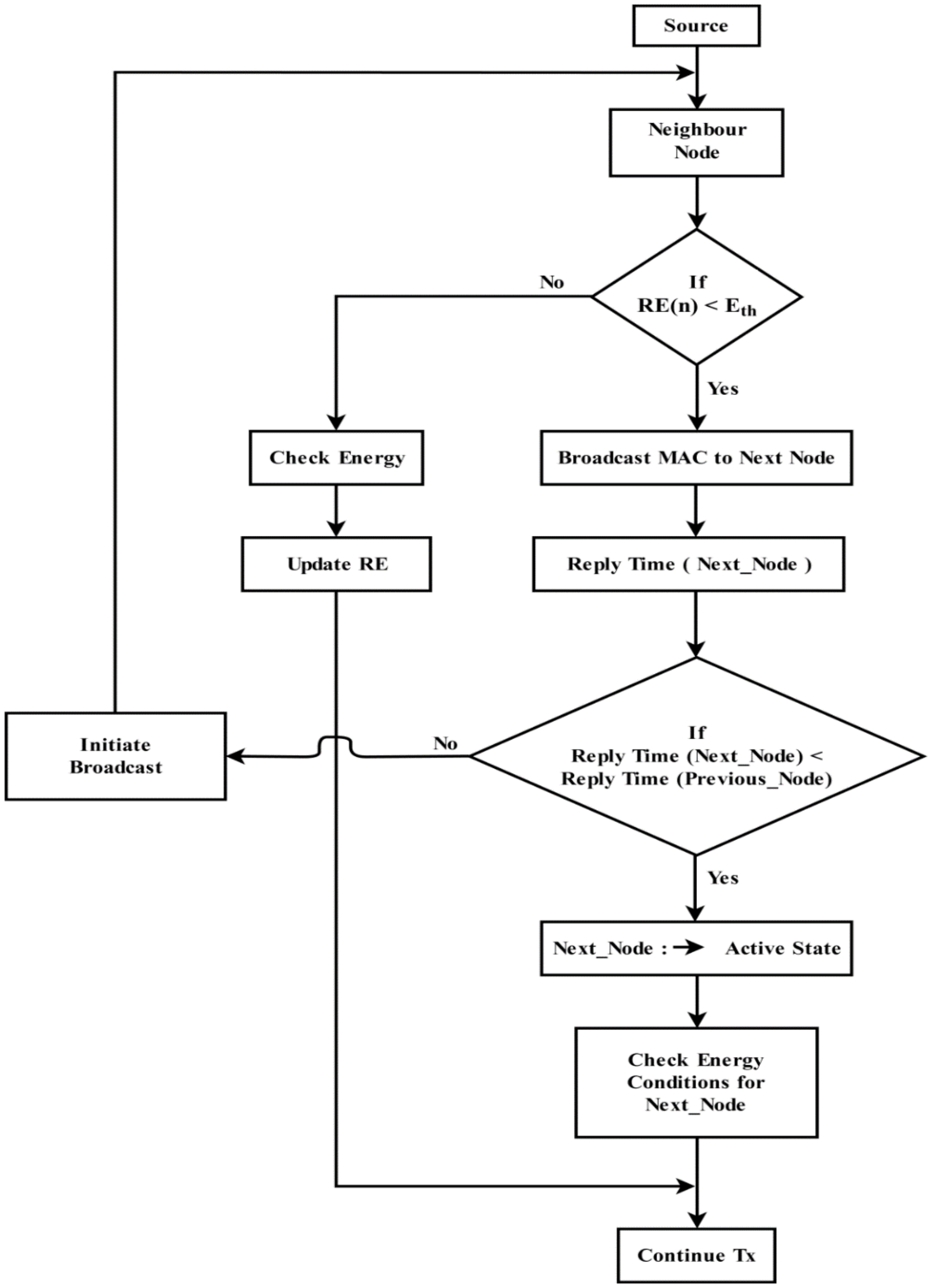

Figure 4: MAC based post relaying process

4. Simulation Results

4.1 Performance metrics

In this section, the simulation results were present to illustrate the efficiency ofthe proposed scheme. First the metrics used for performance evaluation are analysed.

Throughput

Average rate of successful data packets (in bit per second) received at destination node over a communication channel.Channel utilization is reflected by this metric.

Average Energy Consumption

Average Energy consumed by all nodes in the network. Energy consumptionshould be as less as possible so as to make impartial utilization of limited battery Power.

Delay

The mean time that elapses between the origins of the packet generation at a sourcenode and the time a packet reaches its destination node.

Overhead

Every resource within the system that might not be strictly necessary to transmit the payload of the communication will be considered as an overhead and should be minimized.The routing overhead reduces the network diameter and hence information updates very speedily. So overhead should be minimized in the network in order to manage the topology of the network.

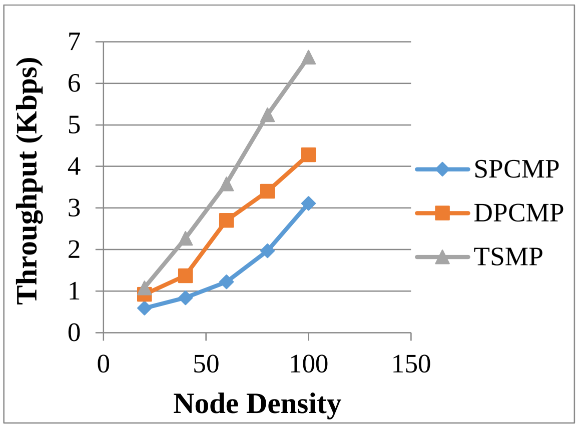

Figure 5: Network throughput vs. node density

The throughput obtained for increased number of nodes is shown in Fig-5. From the graph it is seen that the throughput of proposed is more than SPCMP and DPCMP because when the node density is increased, the throughput of SPCMP decreases more as the node is busy in updating its routing table. DPCMP throughput is also decreased but its value is nominal. It is illustrated that the TSMP approach is adequate to handle scalability and it guarantees that it will offer additional throughput for number dynamic node deployment within the network. The best throughput is obtained by increasing the number of nodes results to increase the node density. Once node density is higher, higher connectivity and also the shorter path is achieved.

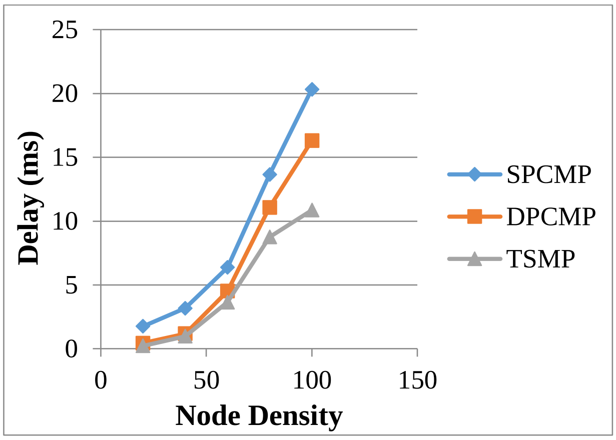

Figure 6: Delay vs. node density

The response time of the proposed approach is shown in Fig-6. It is identified that if the number of the node will increase the throughput is also increased. The data transmission rate in terms of bits has conjointly influenced the delay. As the number of nodes increases, the delay obviously will increase. Minimum delay is required for detector based applications. The delay for all protocols increases with the increase in network size, but the average delay of TSMP is lower than that of SPCMP and DPCMP. When the number of nodes of a network is between 60 and 80,the delay of the proposed protocol is nearly (on average) 11% lower than the delay ofthe DPCMP protocol and even lower than the SPCMP protocol. This is mainly because the proposed protocol selects the path depending on nodes residual energy combined with the average energy of this path. This greatly affects the delay.

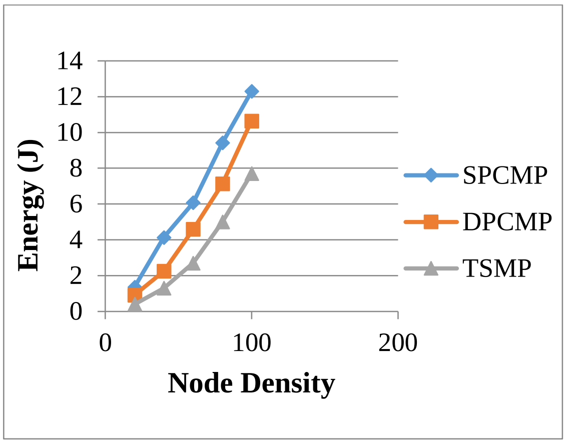

Figure 7: Energy consumption vs. node density

The energy consumption of proposed technique is shown in Fig 7. As node density increases, the probability of finding the neighbour node. Hence the performance of the routing protocol will improve drastically. This may reduce the overall energy consumption in the network, which is otherwise wasted in the routing decisions of network layer protocols. With increased node density, neighbours can be found at a shorter distance from the node. This will require a smaller amount of transmission power and hence transmission energy is saved. This can be illustrated by the Fig 7. Compared to SPCMP and DPCMP, TSMP has less energy consumption with increased number of nodes.

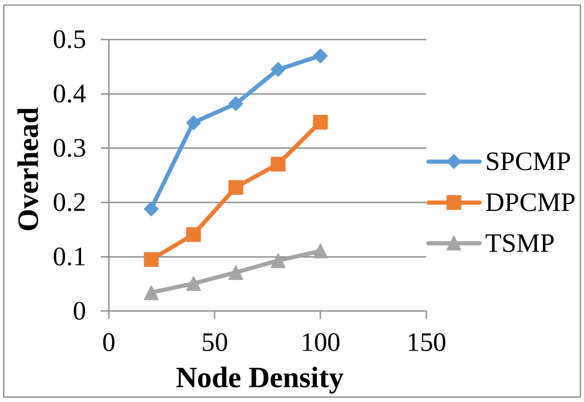

Figure 8: Routing overhead vs. node density

Fig 8 shows the normalized routing load. Proposed work has the most effective performance with an increase of the routing load at a higher mobility. Proposed work routing overhead is over SPCMP and DPCMP as a result of it generates a lot of control packets to find a recent enough route to the destination node. It will increase once nodes move at higher speeds. That's why SPCMP isn't appropriate for large ad hoc network. From this observation, it is concluded that TSMP is best suitable for the dynamic network.

4.2 Simulation parameters

Table 1: Simulation Parameters

Parameters	Values
Simulation area	$1200 \times 1200 m^2$
MAC protocol	802.11
Traffic sources	Constant bit rate (CBR)
Routing protocols	Dynamic Source Routing (DSR)
Antenna type	Omni antenna
Number of nodes	200
Bandwidth	20 MHz
Transmission Power	36 dBm
CST (carrier sense threshold)	1.92278e^{-08}Watt for 250 m
RXT (receiving threshold)	1.92278 e^{-08}Watt for 100 m
Transmission rate	0.1 packets/s
Max. communication range	Up to 125 m.

4.3 Tabulations

Table 2: Performance evaluation of MAC based on throughput

Node Density	Throughput (Kbps)		
	SPCMP	DPCMP	TSMP
20	0.59	0.92	1.08
40	0.84	1.37	2.27
60	1.22	2.7	3.58
80	1.97	3.4	5.24
100	3.11	4.28	6.629

Table 3: Performance evaluation of MAC based on delay

Node Density	Delay (ms)		
	SPCMP	DPCMP	TSMP
20	1.76	0.44	0.23
40	3.18	1.18	0.98
60	6.37	4.52	3.65
80	13.64	11.08	8.76
100	20.33	16.3	10.86

Table 4: Performance evaluation of MAC based on energy

Node Density	Energy (J)		
	SPCMP	DPCMP	TSMP
20	1.36	0.91	0.4
40	4.13	2.24	1.3
60	6.07	4.59	2.7

80	9.42	7.13	5
100	12.3	10.64	7.7

Table 5: Performance evaluation of MAC based on overhead

Node Density	Overhead		
	SPCMP	DPCMP	TSMP
20	0.188	0.095	0.034
40	0.347	0.141	0.0509
60	0.382	0.228	0.071
80	0.445	0.271	0.093
100	0.47	0.348	0.111

From above tabulations it is inferred that TSMP is a reliable and efficent in improving the throughput and energy consumption of the network as it uses transition state based protocol for selecting active nodes in the transmission. Table 2 shows the performance of TSMP in comparison with SPCMP and DPCMP. Thus TSMP in an average it increases the throughput to a maximum extent of 25% and 38% respectively. Table 3 shows the time delay of the network by comparing TSMP with the existing techniques SPCMP and DPCMP. Compared to SPCMP and DPCMP, TSMP gives faster response by 13% to 41%. This is mainly because the proposed protocol selects the path depending on nodes' residual energy combined with the average energy of this path. Likewise, Table 4 present the performance of TSMP in comparison with SPCMP and DPCMP analyzed in terms of total energy consumption. TSMP decreases the total energy consumption rate and delay as it elects a reliable and optimal node by comparing E_c , E_{res} and E_{th} of the nodes. TSMP reduces the total energy consumption to a maximum extent of 14% to 21% higher than DPCMP and 24% to 33% than SPCMP. And comparatively, the routing overhead falls almost 45% to 52% than SPCMP and 27% to 31% than DPCMP.

5. Conclusion

Through this article, a new routing protocol named TSMP for wireless ad hoc networks has been proposed, in which both energy conservation and utilizing the available node in an effective manner prior to their energy drain is achieved. In this proposed technique, the first routing path to the destination is selected based on shortest distance and the rest of the nodes will move to the idle state. After each transmission, the nodes in transmission state will update their energy level (despite the destination)to their predecessor nodes. The predecessor nodes verify the broadcasted energy level with the threshold of each node. If the current energy level of the node is higher than the threshold, then relaying continues, else the node is replaced.Simulation results have shown that the protocol consumes less energy, has a lower average delay and minimizes the overhead. It is concluded that the giventechnique improves the network performance.

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